ON THE USE OF 4D SYNTHETIC TURBULENCE IN A DETERMINISTIC APPROACH TO COMPUTATIONAL AEROACOUSTICS

Roland Ewert, Malte Siefert
Deutsches Zentrum für Luft- und Raumfahrt e.V., DLR
Institut für Aerodynamik und Strömungstechnik
Technische Akustik
Lilienthalplatz 7, 38108 Braunschweig, Germany
roland.ewert@dlr.de, malte.siefert@dlr.de

Broadband noise generated by turbulent motion and especially enhanced in the vicinity of rigid surfaces exhibiting sharp edges is of great technical concern. A typical problem is the sound generated at a high-lift wing of a transport aircraft, which involves low subsonic flow speed at a Reynolds number based on the wing chord length exceeding 10 millions. A great demand exists in industry for the treatment of this type of problems with aeroacoustic design methods that allow for a reliable prediction of acoustic deltas due to geometrical shape and flow changes at turnaround times in the range of less than one day for the computation of each configuration.

Large Eddy Simulation has become a promising tool to resolve the unsteady turbulent flow underlying the aeroacoustics sound generation mechanism up to moderate Reynolds numbers. Direct as well as hybrid methods have been considered for the propagation of the generated sound field into the far-field. However, taking into account the constraints imposed on design methods, it appears rather challenging to apply LES in the early design process within the next 10 years.

Alternatively to the time accurate resolution of turbulence via unsteady flow simulation, in physics the use of synthetic turbulence with deliberately imposed characteristics is considered a valuable and mature way to study turbulence properties, e.g. the implications a distinct turbulence mechanism has for a specific turbulent flow problem. We apply a deterministic CAA approach where the unsteady sound sources are completely prescribed from a 4D space-time model of synthetic turbulence. RANS modeling is used as a simplified approach to model the time averaged turbulent flow problem, which specifies the one- and two-point statistics to be realized by synthetic turbulence. Such a deterministic approach is able to match the tight constraints imposed on a design methodology in the industrial environment with todays computational resources.

The model of 4D synthetic turbulence was introduced in recent works. The Fast Random Particle Mesh (FRPM) involves random particles that move in a way over a background mesh such that very efficiently unsteady turbulence is generated on the mesh. A rich variety of different turbulence characteristics can be realized, such as inhomogeneous and anisotropic fields, where the axis of main Reynolds stresses as well as main integral length scales are allowed to be oriented differently, the convection property of turbulence, a turbulence time de-correlation characteristic that obeys the sweeping hypothesis, as well as different shapes of turbulence spectra. Target values for the local length scale tensor and the turbulent stress tensor can be realized very accurately. Based on these essential prerequisites it becomes now possible to give a mature answer as to which prediction quality can be expected from a RANS based aeroacoustic prediction methodology.

Predictions of the sound generated at a high-lift system will be presented. One essential effect is the scaling of sound intensities with changing flow velocity. We show that this Mach number scaling follows a power law with exponent 4.x for the slat noise problem, which is in very close agreement with experimental findings. Furthermore, the shape of the predicted narrow band spectra matches those of corresponding validation experiments. The capability to predict the effect of geometrical shape variations is validated with experimental results.